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ScienceDirect
Renewable and Sustainable Energy Reviews 13 (2009) 552–566
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Weighing the costs and benefits of state renewables portfolio standards in the United States: A comparative analysis of state-level policy impact projections

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Received 19 November 2007; accepted 7 January 2008

Abstract

State renewables portfolio standards (RPS) have emerged as one of the most important policy drivers of renewable energy capacity expansion in the U.S. As RPS policies have been proposed or adopted in an increasing number of states, a growing number of studies have attempted to quantify the potential impacts of these policies, focusing primarily on cost impacts, but sometimes also estimating macroeconomic, risk reduction, and environmental effects. This article synthesizes and analyzes the results and methodologies of 31 distinct state or utility-level RPS cost-impact analyses completed since 1998. Together, these studies model proposed or adopted RPS policies in 20 different states. We highlight the key findings of these studies on the projected costs of state RPS policies, examine the sensitivity of projected costs to model assumptions, evaluate the reasonableness of key input assumptions, and suggest possible areas of improvement for future RPS analyses. We conclude that while there is considerable uncertainty in the study results, the majority of the studies project modest cost impacts. Seventy percent of the state RPS cost studies project retail electricity rate increases of no greater than 1%. Nonetheless, there is considerable room for improving the analytic methods, and therefore accuracy of these estimates.

Keywords: Renewables portfolio standards; Meta-analysis; Energy market projections

Contents

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1364-0321/$ – see front matter
doi:10.1016/j.rser.2008.01.005

1. Introduction

State renewables portfolio standards (RPS) have emerged as one of the most important policy drivers of renewable energy expansion in the United States [1]. Collectively, these state policies now apply to roughly 50% of U.S. electricity load, and hold the prospect of having substantial impacts on electricity markets, ratepayers, and local economies. Renewables portfolio standards require that a minimum amount of renewable energy is included in each retail electricity supplier's portfolio of electricity resources. They do so by establishing numeric targets for renewable energy supply, which generally increase over time. To date, 24 states in the U.S., along with the District of Columbia, have adopted such standards (Fig. 1). Often, the adoption of new RPS policies hinges on expected costs and benefits.

As RPS policies have been proposed or adopted in an increasing number of states, a growing number of studies have attempted to quantify the potential impacts of these policies, focusing primarily on projecting cost impacts, but sometimes also estimating macroeconomic, risk reduction, and environmental effects. Given the role of these studies in motivating the adoption of state RPS policies, in this article we review 31 previous state RPS cost-benefit projections to compare forecasted impacts across studies. We summarize, in as consistent a fashion as possible, the results of these 31 cost-impact analyses, primarily focusing on the projected costs of state- and utility-level RPS programs. In so doing, we hope to illustrate the expected bounds of likely impacts. We also highlight and, in some cases, critique certain key assumptions used by these studies, with a goal of identifying areas of improvement for future RPS analyses. Though we focus on state-level RPS cost-impact analyses, the recommendations that we develop also hold for national-level analyses of RPS proposals in the U.S. and elsewhere. For the interested reader, the results presented here are discussed in further detail in a report by the same authors (see ref. [2]).

The article is organized as follows:

- Section 2 briefly summarizes the studies included in our sample by characterizing the study authors and the general modeling approach used to estimate cost impacts.
- Section 3 presents the methods used in this article to analyze the results from the 31 state-level RPS cost studies included in our sample.
- Section 4 provides a summary and comparison of the renewable resource mix and direct cost impacts projected by the state RPS cost studies.
- Section 5 identifies any alternative scenarios that were analyzed by the state RPS cost studies, and presents the anticipated costs associated with those scenarios.
- Section 6 highlights some of the more important assumptions that the state RPS cost studies used in modeling renewable resources and avoided costs.
- Section 7 summarizes, very briefly, the nature of the RPS-induced benefits that were evaluated by the studies in our sample though, in the interest of space, we do not discuss these results in any detail.
- Section 8 concludes by summarizing our key findings and highlighting areas of possible improvement for future RPS cost-impact studies.

2. Overview of studies

Twenty states, covering most regions of the United States, are represented by the 31 RPS cost studies surveyed here. Fig. 2

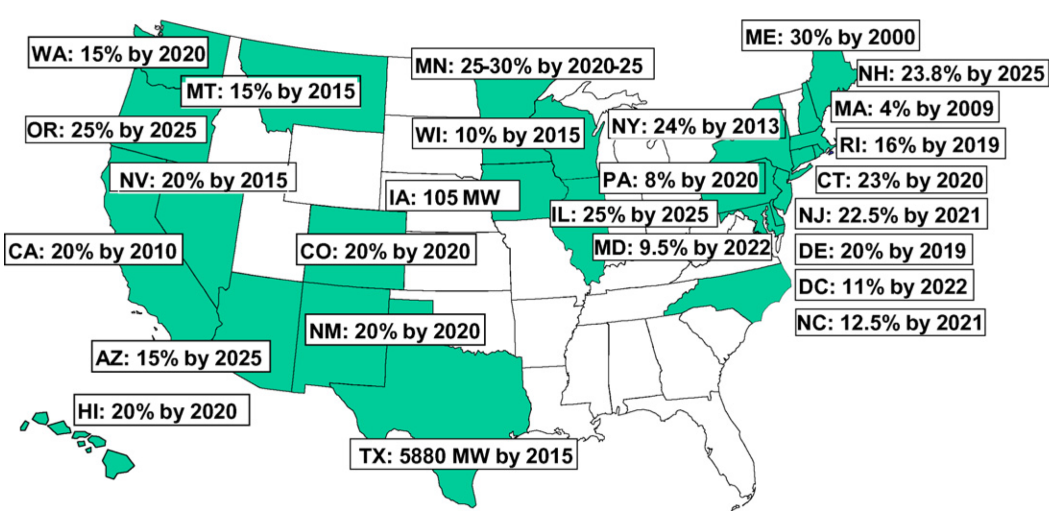


Fig. 1. State RPS policies currently in place (September 2007).

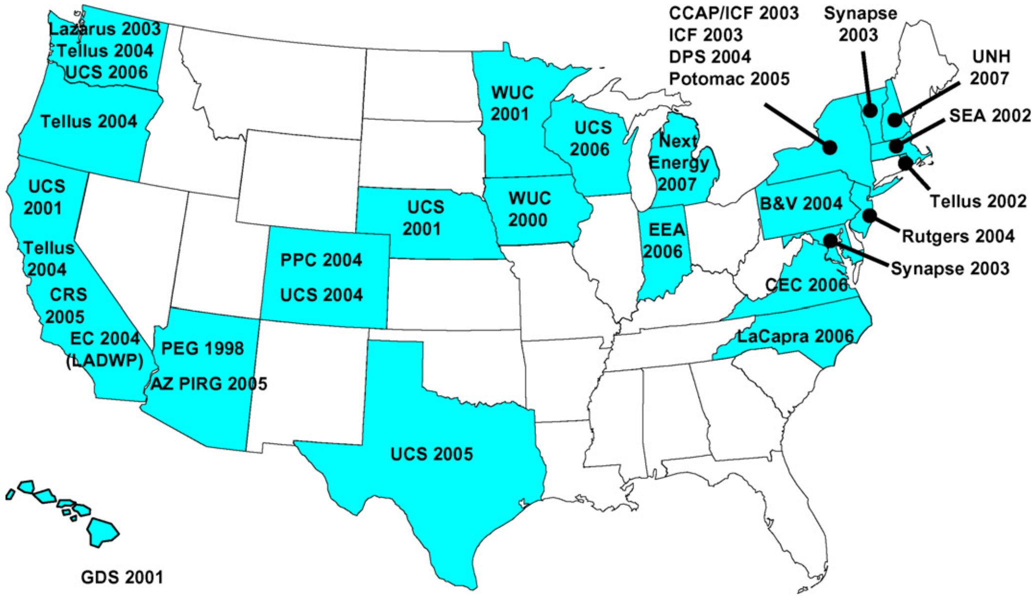


Fig. 2. State RPS cost-impact studies included in report scope.

identifies the authors of the studies in our sample, as well as the states covered by these studies. The full title, authors, and links to each study can be found in Appendix A. We limit our sample to state or utility cost-impact analyses conducted since 1998. Twenty-four of the 31 studies have been published since 2003, however, reflecting the recent surge in state RPS adoption.

The publication of most of the studies in our sample was timed to coincide with state RPS legislation that had been proposed or implemented, and many studies evaluate state RPS policies designed as proposed or implemented through that legislation. Less frequently, some studies advance their own proposals for state RPS legislation. As one might therefore expect, the state RPS policies modeled by these studies differ substantially with respect to structure, design, and quantitative target level. Table 1 briefly summarizes some of the most pertinent details of the state RPS policy designs that are modeled by the cost studies in our review.[1]

The studies, as shown below, are authored and funded by a diverse set of organizations. Diversity also exists in analytical approaches and sources of data used among the studies.

2.1. Authorship and funding sources

The vast majority of studies in our sample have been authored by consultants (roughly 55%) and non-governmental organizations (NGOs, over 35%). Funding has predominantly come from non-profit foundations and interest groups (representing roughly 52% of primary funding sources) and state utility commissions or energy agencies (representing roughly 32% of primary funding sources).

Some of these studies were conducted as part of an extended public process. These reports typically involved the participation and input of diverse stakeholder groups, and in some cases were part of a larger, state-sponsored regulatory proceeding that allowed for public comments on draft versions of the study. Most of the studies in our sample, however, were not distributed for broad public review prior to publication. It is also noteworthy that many of the reviewed studies have been produced by organizations and authors that are strongly supportive of state RPS policies, whereas relatively few of the studies have been funded or conducted by opponents to such policies. This article does not attempt to account for any potential bias that might result from the type of study author or funding source, though it does scrutinize the studies' methods and assumptions more generally.

2.2. General modeling approaches

The studies use a range of different analytic methods that do not always lend themselves to clear categorization. For descriptive purposes, we identify four broad categories of cost-estimation models, listed below with the percentage of studies that fall into each category in approximate order of increasing complexity. These approaches differ in the methods used to characterize the cost of renewable energy and the avoided cost of conventional fuels that are displaced by renewables deployment.

- Category A (58%): spreadsheet model of renewable generation and avoided utility cost.
- Category B (13%): spreadsheet model of renewable generation and generation dispatch model of utility avoided cost using reference-case resource mix.

[1] Table 1 primarily identifies the "base-case" state RPS policies analyzed in each study; many of the studies evaluate multiple RPS designs as alternative cases which are discussed in Section 5. We use the term "base case" to represent the baseline state RPS scenario (as compared to the alternative RPS scenarios described in more depth in Section 5), while we use the term "reference case" to refer to the business-as-usual, non-RPS scenario.

Table 1
State RPS policies as modeled by cost studies

Study	Overall RPS target	Incremental renewables needed to meet target	Year target is reached	Additional notes
AZ (PIRG)	20%	20%	2020	
AZ (PEG)	1%	1%	2002	Only eligible technology is solar
CA (CRS)	33%	16.7%	2020	Target percentages are measured with respect to the load of investor-owned utilities
CA (UCS)	20%	13.2%	2010	
CA (Tellus)	33%	11.2%	2020	Incremental to existing 20% RPS
CA LADWP (EC)	20%	20%	2017	RPS applies only to the Los Angeles Department of Water and Power (LADWP)
CO (PPC)	10%	6.5%	2015	Update to earlier study; includes credit multiplier for in-state resources and 0.4% set-aside for solar
CO (UCS)	10%	6.3%	2015	Includes credit multiplier for in-state resources and 0.4% set-aside for solar
HI (GDS)	9.5%	3.8%	2010	Also models a 10.5% RPS target
IA (WUC)	10%	8.6%	2015	
IN (EEA)	10%	10%	2017	
MA (SEA)	7%	7%	2012	2002 Update to original 2000 study
MD (Synapse)	7.5%	7.5%	2013	
MI (NextEnergy)	7.0%	4.4%	2016	Also models 15% by 2025
MN (WUC)	9%	9%	2010	
NC (LaCapra)	5%	5%	2017	Also models 10% target
NE (UCS)	10%	10%	2012	
NH (UNH)	23.8%	16.3%	2025	Includes solar tier of 0.3%
NJ (Rutgers)	20%	13.5%	2020	Incremental to existing 6.5% RPS; includes incremental solar tier of 0.64%
NY (CCAP)	8%	5.2%	2012	
NY (ICF)	25%	8%	2013	Resource tiers: at least 0.4% fuel cells and 0.4% solar PV
NY (DPS)	25%	7.7%	2013	2004 update to original 2003 and 2004 studies; includes 0.15% customer-sited tier
NY (Potomac)	25%	6.9%	2013	Includes 0.15% customer-sited resource tier
OR (Tellus)	20%	10.6%	2020	
PA (B&V)	10%	7.2%	2020	Update to earlier study; two-tiered RPS, but we only include results from the renewable energy tier
RI (Tellus)	20%	18.4%	2020	Also models 10 and 15% targets
TX (UCS)	10,000 MW	2.7%	2025	Also models 20% by 2020 target
VA (CEC)	20%	16.9%	2015	Also models 15% target
VT (Synapse)	10%	10%	2015	Also models 5 and 20% targets
WA (Lazarus)	15%	15%	2023	RPS includes efficiency, but 15% target identified here only reflects renewables
WA (UCS)	15%	11.9%	2020	RPS includes efficiency, but we only include results attributable to the renewable additions
WA (Tellus)	20%	16.6%	2020	
WI (UCS)	10%	7.2%	2015	2006 update to original 2003 study

- Category C (6%): spreadsheet model of renewable generation and generation dispatch model of utility avoided cost using implied RPS resource mix.
- Category D (23%): integrated energy model.

Overall, this diversity of modeling approaches indicates that a standard template for RPS cost estimation has yet to emerge. One might assume that accuracy increases with each modeling approach from Category A to Category D, as each successive model tends to provide more detail and captures more complexity. Integrated national energy models, however, are often designed with a national resolution, and may therefore not be able to fully incorporate the range of regionally oriented RPS design details inherent in proposed state RPS policies. In addition, not enough is yet empirically known about the actual cost impacts of state RPS policies to validate the accuracy of one model over another. Energy markets are subject to significant uncertainty, and future renewable energy costs, while less volatile than conventional electricity prices, are also uncertain. As a result, the assumptions governing these costs may ultimately prove more important than the choice or complexity of the model itself.

3. Methods

The general approach employed in this article is to distill the results and details about the methodologies of these state RPS studies into comparable metrics in order to understand broad trends in the study results and methods.

The studies in our sample present projected RPS costs in many different ways. Though most studies report expected retail rate impacts, some studies only report changes in electricity sector generation costs. In addition, the studies use different units to convey cost results. Developing a consistent set of metrics for comparing cost projections across studies is therefore necessary. To do so, we compare cost projections using two metrics that are easily understood and, where necessary, are readily converted from other data: (1) percentage changes in retail electricity rates, and (2) monthly electricity bill impacts for a typical residential household. To further facilitate comparisons, all cost data have been converted to real 2003 dollars.

Each study also uses a different timeframe for its analysis, and the studies report expected costs using a variety of different time horizons; they may report annual costs, costs averaged over a given timeframe, and/or the present or net present value of RPS-induced costs. More generally, comparing results among a group of studies that themselves have individually been conducted over a span of several years is potentially problematic because underlying conditions may have changed over this period. Perhaps most obviously, natural gas prices (and price expectations) are much higher today than they were in years past, so a state RPS study conducted several years ago would naturally yield different results than one conducted in the same manner today.

Given these challenges, complete comparability across all of the studies in our sample is simply not possible. Nonetheless, we temporally normalize the results from the different studies by presenting results from the first year that each state RPS reaches its ultimate target level.[2] Though an imperfect metric for characterizing the full trajectory of projected cost impacts and renewable resource additions within each study, using the results from the initial peak year is a tractable and consistent method for comparing impacts across studies. The projected costs of RPS policies in these initial peak target years also tend to be the highest or close-to-highest of the cost impacts from all of the years that are modeled, allowing us to avoid under-representing the potential long-term costs of such policies.

4. Projected renewable resource mix and direct costs of RPS policies

This section summarizes two of the most important outputs of the state RPS cost-impact studies: the projected impacts of state RPS policies on renewable energy deployment by technology and on the direct costs of that deployment. In the former case, we present the expected amount of generation from each renewable technology used to meet the state RPS policies. In the latter case, we define direct costs to include the impact of renewables deployment on retail electricity rates and bills. Direct costs include not only the incremental costs (if any) of renewable generation, but also wholesale electricity price reductions (from the displacement of high-cost marginal supply), including any electricity price reduction caused by lower natural gas prices; these impacts are included as direct effects because they influence consumer electricity bills. Some benefits that might derive from RPS policies, but that are not included in the direct cost calculations, are discussed later, in Section 7.

4.1. Projected renewable resource mix: base-case results

Though most of the studies in our sample are focused on cost impacts, the majority (26 of 31 studies) also forecast the mix of renewable technologies most likely to be used to meet state RPS requirements (typically assuming that the least-cost renewable resources are selected before the more expensive ones). Figs. 3 and 4 present the projected mix of new renewable generation used to meet the modeled state RPS policies, both individually and collectively.

Perhaps not surprisingly, wind is expected to be the dominant technology, representing 60% of incremental state RPS generation across all of the studies combined. Projected wind deployment is particularly prevalent in the Midwest and Texas, accounting for 94% of projected incremental RPS generation in those states. Geothermal, which accounts for 17% of projected incremental generation across the studies, is a distant second, and almost all of the expected geothermal additions are from the California studies. Biomass co-firing and direct combustion account for approximately 11% of expected incremental state RPS

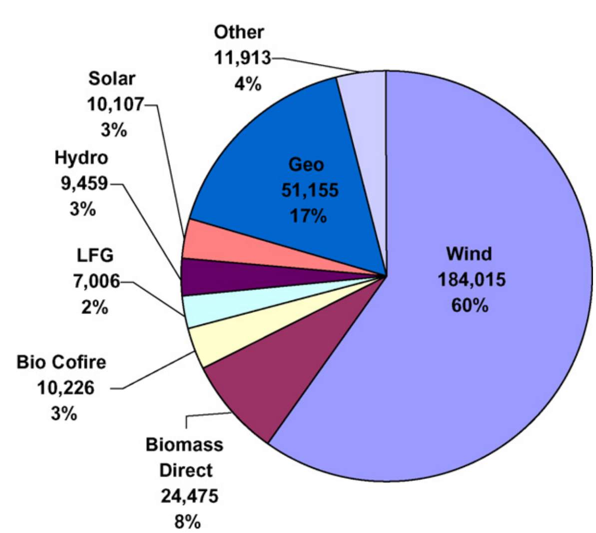


Fig. 3. Mix of incremental renewable generation from all studies combined (GWh, %).

[2] Due to data limitations, we were required to allow a few exceptions to this rule. Because Arizona (PEG) does not provide annual cost data, we use average 1998–2030 data as a proxy for long-term rate impacts. Iowa (WUC) provides only averaged data, so we use data averaged over 2005–2014. We interpolate between 2010 and 2015 data from New York (CCAP) to approximate estimates for 2012 (the initial peak target year of the state RPS policy modeled in the study).

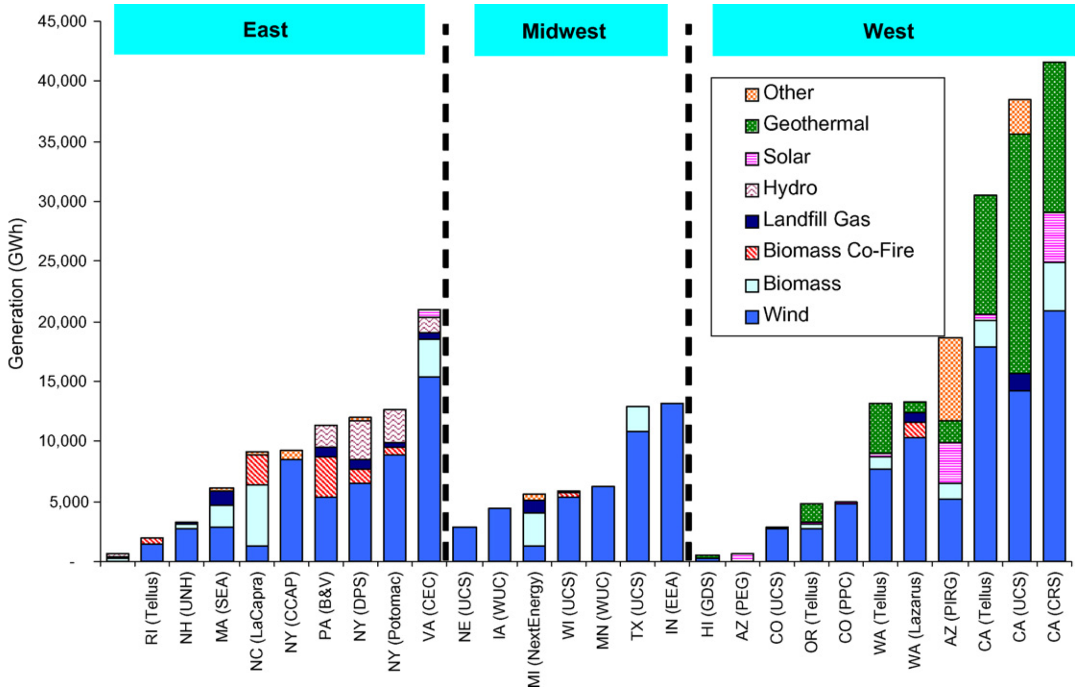


Fig. 4. Incremental renewable energy deployment by study and technology.

generation, while hydro, landfill gas, and solar each comprises less than 4%.[3]

4.2. Direct cost impacts: base-case results

Fig. 5 summarizes projected electricity rate impacts in percentage and ¢/kWh terms, for each individual state RPS cost study (focusing on the base-case scenario). On the whole, state-RPS-induced rate impacts are typically projected to be relatively modest. More than half of the reviewed studies report base-case rate increases of between 0 and 1%. Six studies project that electricity consumers will experience cost savings as a result of the state RPS policies being modeled, at least in the base-case scenario. On the other extreme, ten studies predict rate increases above 1%, and two of these studies predict rate increases of more than 5%.

Among our sample, the median projected increase in retail electricity rates is 0.8%, or 0.05 ¢/kWh. Relatively few studies predict increases in retail electricity rates that exceed 0.25 ¢/kWh. The largest cost savings are reported in the Texas (UCS) study, which estimates that the modeled Texas RPS could reduce consumer electricity costs by 5.2% (−0.4 ¢/kWh) compared to the business-as-usual reference case. The largest rate increase is predicted by the Arizona (PIRG) study, which estimates that electricity rates in the state could increase by 8.8% (0.7 ¢/kWh) compared to the reference case.

[3] These percentages are purely intended for illustrative purposes. They do not represent the overall RPS mix that would be developed if RPS policies were adopted in all of the states for which cost studies have been performed. Renewable energy deployment data are not available for all states, and multiple cost studies exist in some states, thereby "double counting" the impacts of those states' RPS policies on these percentage figures.

These outlying rate projections are a function of the assumptions used in each study. The Texas (UCS) study assumed that the large amount of wind development resulting from the Texas RPS would have ripple effects on the national level. Specifically, the model assumed that the significant amount of Texas wind capacity additions would stimulate wind technology cost reductions on the national level, which would lead to increased wind development and greater natural gas price savings nationwide. In the case of the Arizona (PIRG) study, the high rate impact projections are in large part due to the study's assumption that 20% of the required RPS generation would be produced by relatively high-cost solar technologies.

Though most of the studies project relatively limited impacts on retail electricity rates, the wide range of impacts shown in Fig. 5 underscores the large variability among the studies' cost results. In fact, cost results can vary widely even within a single state. For instance, two of the three cost studies that analyze essentially the same RPS design in New York estimate retail rate increases of less than one percent (DPS and Potomac), while the third (the ICF study) projects the second highest cost increase of any study in our sample. These differences reflect variations in assumed input parameters, in particular about the future cost and availability of renewable energy generation.

Direct costs can also be presented as the expected increase in an average residential consumer's monthly electricity bill. Fig. 6 presents projected cost impacts in this form, along with error bars for those studies that include scenario analyses in addition to the base-case analysis. As shown in this figure, cost studies of state RPS policies in Eastern states (and, more specifically, in Northeastern states) generally forecast higher cost impacts than studies of state RPS policies in other parts of the country. Four of the six highest projected RPS-induced cost impacts are from studies of Eastern states. The higher expected costs in the East are

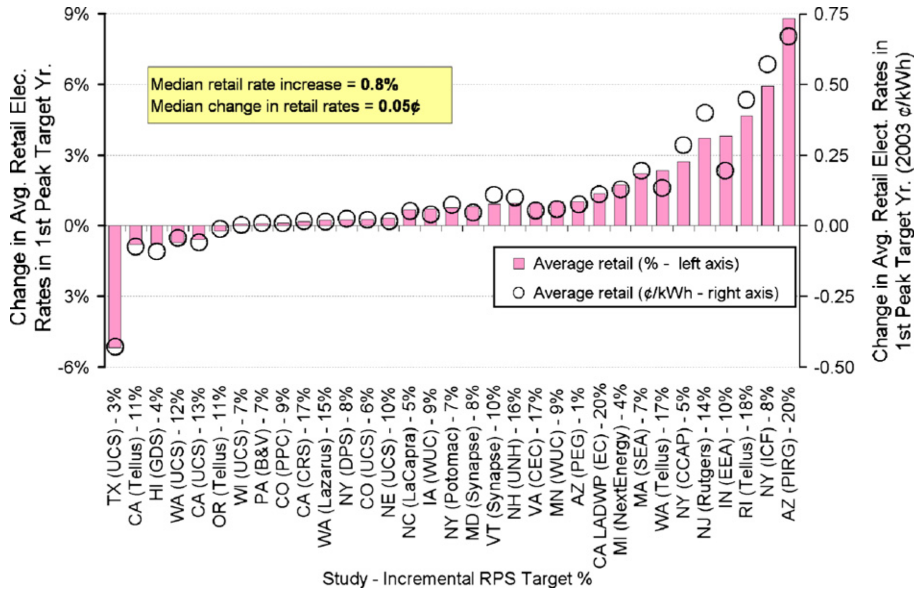


Fig. 5. Projected electricity rate impacts by RPS cost study.

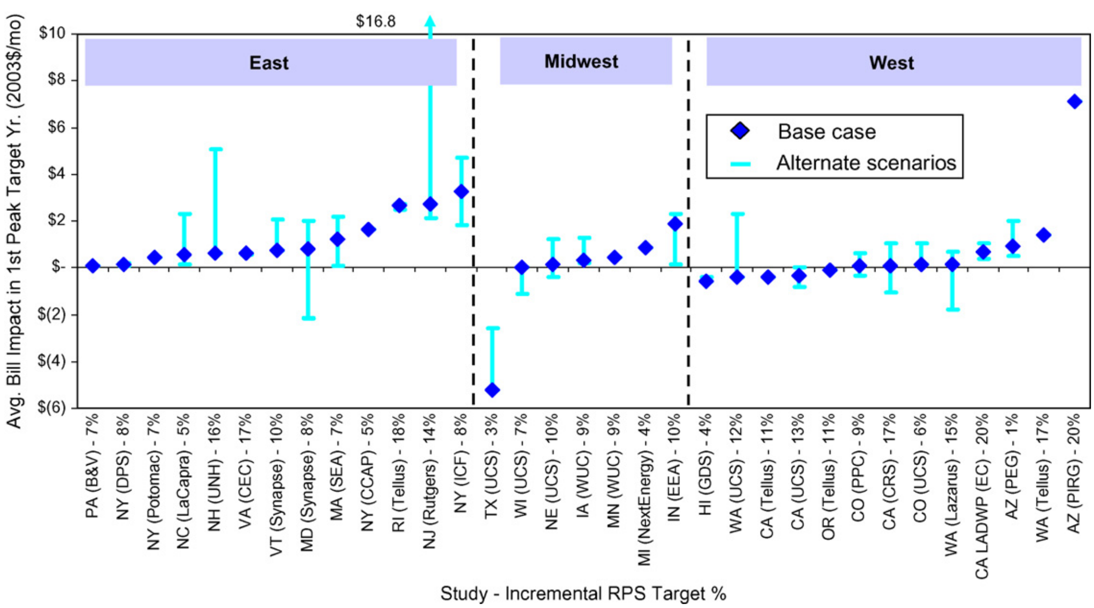


Fig. 6. Typical residential electricity bill impacts projected by RPS cost studies.

attributable to the region's lower renewable resource potential compared to elsewhere in the country and the higher costs of developing renewable projects in the Northeast. Though the predicted costs of state RPS policies in the East may be relatively high compared to those in the rest of the country, the median monthly residential bill impact among the Eastern studies is still modest, at $0.75 per month. Among the other (non-Eastern) states, the median monthly bill impact for an average household is $0.14 per month. All but four of these studies forecast monthly bill increases of less than $2.00 for an average household.

5. Scenario analysis

Estimates of the future cost of state RPS policies are highly uncertain, and are greatly influenced by assumed input

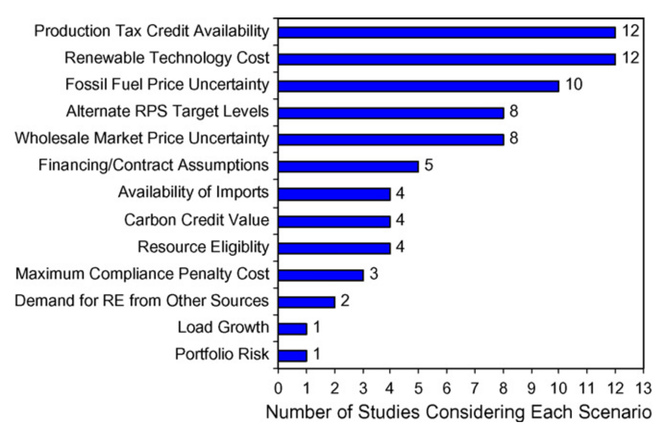


Fig. 7. Sensitivity scenarios modeled by RPS cost studies.

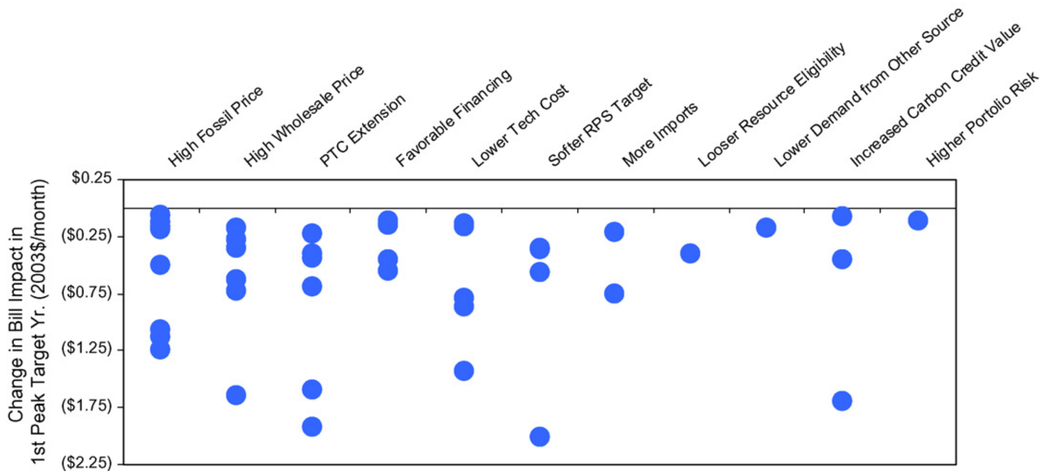


Fig. 8. Changes to base-case residential monthly electricity bill impacts by individual driver (cost decreasing scenarios).

parameters. Because of this, 24 of the 31 studies we reviewed include some form of scenario analysis using input assumptions that differ from those used in the base-case analysis.

Among the studies we reviewed, the scenarios that are most commonly modeled include variations in the assumed availability of the federal production tax credit, varying projections of renewable technology costs, fossil fuel price uncertainty, alternative RPS targets, and wholesale market price uncertainty (Fig. 7).

The full range of sensitivity scenarios modeled by the state RPS cost studies in our sample are briefly and qualitatively described below:

- Production Tax Credit availability: reflects changes to the assumed duration of federal production tax credit (PTC) availability.
- Renewable technology cost: reflects changes to base-case renewable technology cost, fuel, and performance assumptions.
- Fossil fuel price uncertainty: reflects changes to reference case fossil fuel (typically natural gas) prices.
- Wholesale market price uncertainty: reflects changes to reference case wholesale electricity market prices.
- Alternate state RPS target levels: reflects variations in the state RPS percentage target.
- Financing/contract assumptions: reflects changes to base-case renewable financing terms and/or different contractual arrangements for procuring renewable power.
- Availability of imports: reflects variations in the treatment of renewable power or RECs that are imported from nearby states or regions.
- Carbon credit value: reflects the value of renewable energy in reducing carbon dioxide emissions, especially if future regulations limit such emissions.
- Resource eligibility: reflects different definitions of RPS-eligible renewable generating technologies.
- Demand for renewable energy from other sources: reflects changes in demand for eligible renewable energy supply from other sources, such as voluntary green power programs or RPS policies in neighboring states.
- Maximum compliance penalty cost: reflects an assumption that electricity suppliers will pay the non-compliance penalty or alternative compliance payment that applies to the state RPS. Penalties and alternative compliance payments can sometimes bound the maximum possible cost of a state RPS, because suppliers may choose to pay the penalty or alternative compliance payment when it presents a less costly alternative to purchasing renewable energy or RECs.
- Load growth: reflects changes to load growth assumptions.
- Portfolio risk: reflects the cost risk associated with a given electricity generation portfolio. Depending on their resource constitution, state RPS generation portfolios may have different levels of risk (with corresponding differences in rate impacts).

Due to the wide range of scenarios modeled and the different assumptions used within each type of scenario, it is difficult to draw definitive conclusions about the relative impact of different cost drivers. Figs. 8 and 9, however, show the expected cost impacts of all of the scenario types modeled in the state RPS cost studies that we reviewed.[4] Within a data column, each marker represents the change in projected monthly residential electricity bill impacts caused by an individual scenario from a single state RPS cost study. Fig. 8 presents data on scenario types that result in lower state-RPS-induced electricity bill impacts, while Fig. 9 presents data on scenario types that generally result in higher electricity bill impacts.[5]

Most individual scenarios do not appear to have major impacts on the projected base-case RPS costs. With few exceptions, the residential electricity bill impacts of these scenarios – as measured by changes from the base-case – are less than $1 per month. Though such changes are not

[4] Some studies model more than two scenarios for each scenario type, e.g. three different natural gas price forecasts instead of just a high and low forecast. In these instances, we include only the two scenarios (one cost-decreasing and one cost-increasing) that have the greatest impact on rates.

[5] The data presented in these two figures differs from the error bars shown in Fig. 6 because Fig. 6 includes ‘‘combination’’ scenarios in which multiple input assumption changes are made simultaneously.

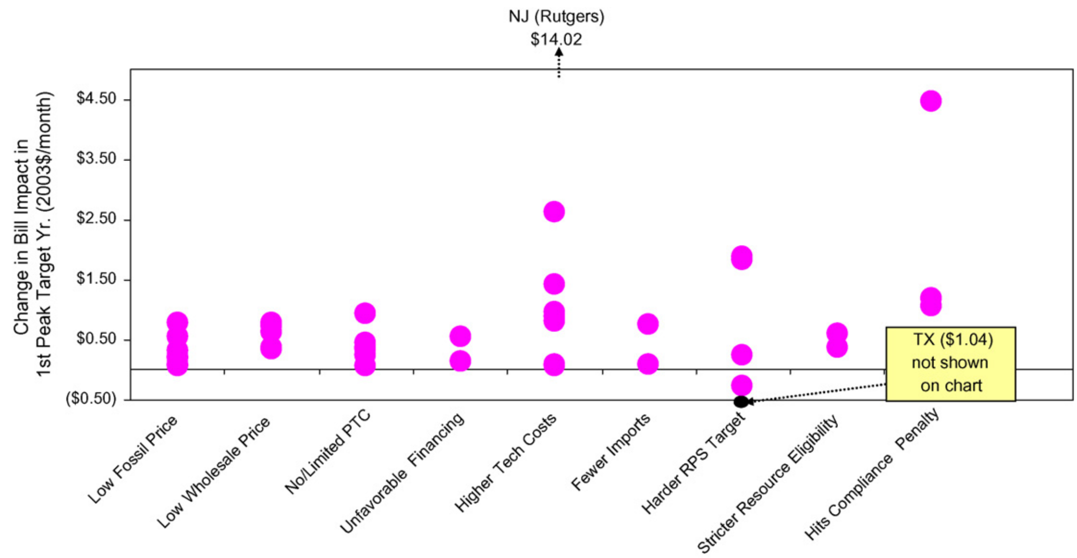


Fig. 9. Changes to base-case residential monthly electricity bill impacts by individual driver (cost increasing scenarios).

overwhelming, it is important to recognize that the median base-case residential electricity bill impact among the studies in our sample is just $0.46 per month, with a range of −$5.2 to 7.1 per month. Therefore, even a $1 per month change from this base-case is sizable in percentage terms, and demonstrates significant cost sensitivity to input parameters.[6]

6. Evaluation of key input assumptions

Potentially more important than the specific modeling approach used by any individual study are the various assumptions required to model long-term costs. The cost of RPS policies will greatly depend on the cost of the renewable technologies employed to meet the RPS targets, the cost of energy that is displaced by the increase in renewable resources, the availability of incentives to reduce the cost of renewable resources, and the secondary costs associated with deploying renewable technologies.

A comparison of the assumptions across the RPS cost studies in our sample reveals that key assumptions are by no means uniform across studies and in some cases may under- or over-estimate costs. In this section, we examine in detail differences in four major input assumptions: the capital cost of wind technology, future natural gas prices, the future availability of the federal production tax credit, and secondary costs associated with renewable energy deployment.

[6] In some cases, scenarios result in incremental costs well above US$ 1/month for an average household. The most conspicuous example is the New Jersey "high technology cost" scenario, which exceeds the base-case bill impact by about US$ 17/month (see Fig. 6). This is largely explained by the relatively high amount of solar energy required by the New Jersey RPS, which would result in substantially higher costs if the technology does not become more economic over time. In reality, higher-than-expected solar technology costs would probably cause legislators to change the RPS policy to require less solar energy rather than allow state RPS rate impacts to reach such an extreme level.

6.1. Wind capital cost assumptions

Wind power is often found to be the least-cost renewable energy source and, as noted earlier, wind is therefore expected to be the dominant technology in meeting state RPS requirements. As such, the assumed cost of wind can have a major impact on the projected cost of RPS policies. For example, a change in wind capital costs of $100/kW roughly corresponds to a $5/MWh change in levelized generation costs.

We find that the assumed cost of constructing wind projects varies considerably among the studies in our sample. Among the 19 studies that present these data, for example, the highest capital cost estimate in the 2010–2015 timeframe (from Scenario 1 of the New York ICF study) is four times higher than the lowest estimate (from the Vermont study). More generally, however, of the studies reviewed here, most predict wind capital costs of under $1300/kW, and some predict long-term costs well below this figure. Notable is that current wind costs are in the $1600–2000/kW range [3], driven higher in recent years by adverse exchange rate movements, rising energy and steel prices, tight wind turbine manufacturing capacity, and a general rush to install wind projects while the federal production tax credit remains in place. As a result, the wind cost assumptions employed in most of the state RPS analyses presented here do not accurately reflect the current cost to build a wind project. This disparity between study expectations and current market reality suggests that (all else being equal) the actual cost impacts of state RPS policies may exceed those estimated in our sample of studies, especially if higher wind costs persist.

6.2. Natural gas price forecasts

The difference between renewable energy costs and the cost of conventional power that would otherwise be used to meet load largely determines the projected rate impacts of RPS policies. In many studies, the most important input to the avoided cost calculation is the natural gas price forecast. This is

due to two factors: (1) natural gas prices are highly uncertain, especially when compared to coal prices, making gas prices particularly difficult to predict; and (2) the majority of studies expect that increased renewable generation will largely displace natural gas-fired generation.

The natural gas price forecasts used by the RPS cost studies in our sample have significant price discrepancies in the short term, though projected prices converge to some degree in the longer term. Despite these variations, it is apparent that relatively low natural gas price forecasts were used by many of the studies in our sample. The average base-case delivered natural gas price forecast in the initial peak target year of our study sample (2010–2025, depending on the study) is just $4.81/MMBtu. Prices for 2007–2011 NYMEX natural gas futures, on the other hand, as well as the most recent fundamental based natural gas price forecasts, have shown much higher price levels than the majority of the forecasts used in the cost studies. As such, though low assumed wind costs have tended to result in under-estimates of the costs of RPS policies, the low forecasts of natural gas prices have tended to push cost projections in the other direction.

6.3. *Federal production tax credit (PTC) availability*

The federal PTC can ‘‘buy-down’’ the cost of renewable energy by roughly $20/MWh on a long-term, levelized cost basis. As such, assumptions about the future availability and level of the PTC can greatly impact the predicted cost of state RPS policies.

The assumed duration of PTC availability lacks consistency across studies, reflecting the political uncertainty surrounding PTC extension. The final year of PTC availability in our sample of studies is most commonly assumed to be 2006. Eight studies, however, assume PTC availability throughout the entire timeframe of their analysis, while nine studies do not appear to include the PTC in their analysis at all. Though the PTC was recently extended through the end of 2008, its long-term fate remains highly uncertain. As shown earlier, several studies have appropriately reflected this uncertainty in their analysis by modeling various PTC availability scenarios.

6.4. *Treatment of secondary costs*

Finally, to accurately reflect the true cost of renewable energy, it is not sufficient to only estimate busbar economics. Instead, a variety of secondary costs and impacts must also be considered, including: transmission costs, operational integration costs, the cost of achieving resource adequacy, and administration and transaction costs. These costs can be significant, especially for wind power, and can be particularly important in regions with transmission constraints and aggressive RPS targets (see, e.g., refs. [4–6]).

The fact that many of the studies in our sample ignore some subset of these costs suggests that predicted RPS costs may be underestimated by these studies, all else being equal. For example, though roughly half of the cost studies in our sample include transmission costs in their analysis, few of the studies analyze these costs in a detailed fashion. Similarly, only 12 of the studies in our sample include the cost of integrating wind power into the electricity system.

7. A brief synopsis of the projected benefits of RPS policies

Many of the studies in our sample also evaluate the potential public benefits of RPS adoption, many of which are not directly factored in to the direct cost results presented earlier. These benefits can be divided into three main categories: macroeconomic, risk mitigation, and environmental. Fig. 10 identifies the number of studies in our sample that model each of these potential benefits.

Of those studies that evaluate possible macroeconomic influences, all but one predict some level of net employment gain, ranging from a few hundred to several thousand jobs created, but the magnitude of this impact varies widely and appears to depend more strongly on the assumptions of the studies than on the amount of incremental renewable generation required to meet the modeled state RPS policies. These assumptions include the different mixes of renewable technologies developed, the proportion of in-state versus out-of-state renewable project development and manufacturing, and the incorporation (or lack thereof) of energy bill impacts into the macroeconomic analysis. That growth in renewable energy generation may increase net employment is consistent with past analyses, which have often shown renewable energy to be more labor-intensive than conventional forms of electricity production (see, e.g., refs. [7,8]).

A number of the studies in our sample also model the risk mitigation benefits of an RPS, estimating a broad range of reductions in wholesale electricity and natural gas prices, while other studies evaluate the sensitivity of the projected cost of state RPS policies to variations in the projected price of natural gas. These analyses build – to some degree – off of recent analytic work by others (see, e.g., refs. [9–13]), and often find that the risk-mitigation benefits of renewable energy are sizable. For example, the results of these analyses demonstrate that the value of renewable energy is especially great under scenarios of unexpectedly high natural gas and wholesale electricity prices.

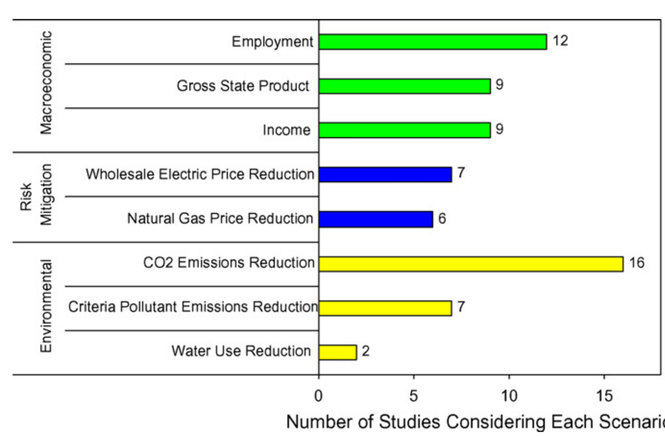


Fig. 10. Potential benefits modeled by RPS cost studies.

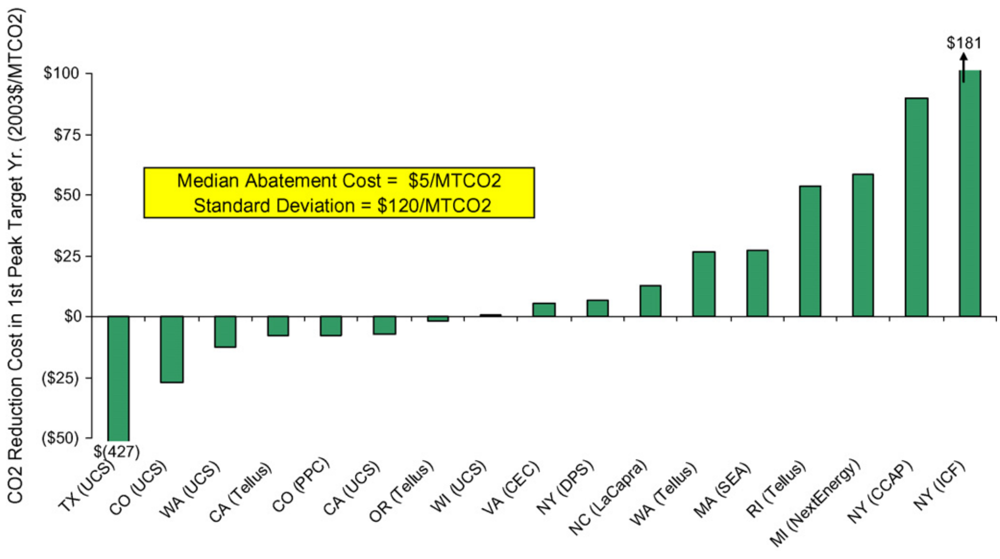


Fig. 11. Projected CO_2 abatement costs in initial peak year of RPS.

Not surprising, many of the studies quantify potential environmental benefits, most commonly carbon dioxide (CO_2) emissions reductions. Most of these studies indicate that RPS generation is expected to displace CO_2 emissions at a rate that is, on average, 25% higher than that of a natural gas plant. Though reductions in carbon emissions is not the sole – or even primary – justification used to support many state RPS policies, Fig. 11 shows the implied CO_2 abatement costs projected by those studies that estimate CO_2 reductions, focusing again on the peak RPS target year of each study.[7] CO_2 abatement costs vary widely, from a low of −$427/MTCO$_2$ in Texas (UCS) to a high of $181/MTCO$_2$ tonnes in New York (ICF), with a median value of $5/MTCO$_2$. The wide variation in CO_2 abatement costs is largely a reflection of the variation in retail rate impact projections among the studies. Although the spread of projected CO_2 abatement costs across the studies is extremely broad, a majority of these studies project CO_2 reduction costs that fall within the range of the U.S. Energy Information Administration's projections of carbon reduction costs under various proposed regulatory regimes, as well as the carbon costs currently being assumed in utility planning [14].

8. Implications and conclusions

With a few exceptions, the long-term rate impacts of state RPS policies as projected by the studies reviewed here are expected to be relatively modest. Only two of the 31 cost studies in our sample predict rate increases of greater than 5%, and 23 of the studies project rate increases of no greater than 1% (with 6 of these studies predicting rate decreases). The median residential electric bill impact is +$0.46 per month, in the peak RPS target year.

The studies in our sample utilize a variety of modeling approaches, methods, and data sources to estimate state RPS costs and benefits. A standard study template has not yet emerged.

It is true that more sophisticated models can account for interesting and potentially significant natural gas and wholesale electricity price feedbacks and may therefore be better received by policymakers and RPS stakeholders. These models may also be better able to capture the benefits of increased renewable energy deployment. It is not entirely clear, however, that such models necessarily improve predictive accuracy, and it may be that the national scope of these models is not fully appropriate for conducting state-level RPS analysis. The assumptions for the primary and secondary costs of renewable energy, as well as the cost of conventional generation offset by increased renewable energy deployment, are likely of far more importance than the type of model used.

Though the RPS cost studies in our sample demonstrate some improvements and increased sophistication over time, additional improvements are still possible and needed. Based on our review, we identify a number of areas of possible improvement for future RPS cost-impact studies:

- Improved treatment of transmission costs, integration costs, and capacity values. Transmission availability and transmission expansion costs have become among the most important barriers to renewable energy in many jurisdictions, but these costs are often poorly understood and imprecisely modeled in RPS cost studies. The capacity value of renewable energy (wind, in particular), as well as the cost of integrating renewable energy into larger electricity systems, are likewise emerging as potentially important variables, and studies analyzing RPS policies with relatively high incremental targets must be careful to properly account for these potential costs and impacts.

[7] These costs were calculated by dividing the base-case direct RPS electricity cost impacts in the initial peak target year of each study by the corresponding estimated CO_2 reductions. Since these are single-year costs, they do not represent the average costs of CO_2 abatement over the lifetime of each modeled RPS policy.

- More rigorous estimates of the future cost and performance of renewable technologies. As the renewable energy market continues to rapidly evolve and expand, the need for accurate, rigorous, and up-to-date estimates of renewable resource cost, performance, and potential is as acute as ever. Unfortunately, some of the most commonly used data sources for the cost and potential of renewable generation technologies are somewhat dated and arguably not up to the task. The use of up-to-date information would improve the credibility of RPS cost analysis and lend more weight to economic analysis of renewable technologies in general.
- Estimating the future price of natural gas. Where possible, base-case natural gas price forecasts should arguably be benchmarked to then-current natural gas futures prices [11]. Furthermore, given fundamental uncertainty in future gas prices, a healthy range of alternative price forecasts should be considered through sensitivity analysis.
- Evaluation of coal as the marginal price setter. With high natural gas prices, some regions are shifting away from natural gas and towards other resources, especially coal. A few of the RPS cost studies already assume that coal is the marginal fuel type that is offset by increased renewable generation, but most of the studies assume that natural gas will be the primary source of displaced electricity generation. New studies should more closely investigate the possibility that RPS generation may increasingly displace coal-fired and other non-gas-fired generation.
- Greater use of scenario analysis. The inaccuracy of long-term fundamental gas price forecasts underscores the importance of using scenario analysis to bound possible outcomes. Not only is the future cost of conventional generation unknowable, renewable technologies themselves are experiencing rapid changes, both of which render the long-term impacts of RPS policies highly uncertain. Such uncertainty can be evaluated, to a degree, through greater use of scenario analysis. Some of the variables that may be most appropriate for scenario analysis include renewable technology potential and costs, future natural gas and wholesale electric prices, and the availability of other renewable energy incentives.
- Consideration of future carbon regulations. As some jurisdictions begin to implement carbon regulations, renewable generators may stand to benefit. Although these trends may significantly reduce the incremental cost of the renewable generation that is required by RPS policies, the risk of future carbon regulation has only been modeled by four of the studies in our sample. In future studies, we recommend that the risk of future carbon regulations be explicitly considered, at a minimum though scenario analysis.
- More robust treatment of public benefits. Though an increasing number of studies have modeled macroeconomic benefits, the assumptions driving these analyses are often inconsistent, and the wide range of results may detract from the credibility of such studies. More work is needed to identify the most feasible and defensible assumptions governing the public benefits of renewable energy, including the fossil fuel hedge value of renewable energy and the benefits of reduced carbon emission, in addition to employment and economic development impacts.

The improvements listed above, if adopted, should lead to more accurate and realistic projections of the costs and benefits of RPS policies in the future. In the meantime, it is difficult to assess whether the RPS cost studies reviewed in this article present overly optimistic or overly conservative estimates of future costs. Some of the assumptions in the cost studies that may result in an underestimation of actual RPS costs include:

- wind capital cost assumptions that appear too low in many cases, given recent increases in wind costs;
- transmission and integration costs that are not fully considered;
- lack of full consideration for the potential demand for renewable energy from other sources, such as demand from other state RPS policies;
- increased likelihood that coal-fired generation will set wholesale market prices in some regions which, in the absence of carbon regulations, may make renewable generation less economic than when renewable energy is presumed to compete with natural gas;
- expectations in some cases that the federal production tax credit (PTC) will be available indefinitely, which may be overly optimistic given the political uncertainty affecting PTC extension.

Conversely, a number of other cost study assumptions may result in an overestimation of actual RPS costs, including:

- reliance on natural gas price forecasts that are almost universally substantially below current price expectations;
- the impact of renewable energy in reducing natural gas and/or wholesale electric prices that have not been modeled in many of the studies;
- the potential for future carbon regulations, which are ignored in most of the studies in our sample;
- expectations in many cases that the PTC will only be available for either a very limited period or not at all, which may be overly conservative.

Actual RPS costs may differ from those estimated in the cost studies summarized in this article. As states accumulate more empirical experience with actual RPS policies, future analyses should benchmark the cost projections from RPS cost studies against actual realized cost impacts as a way to both inform future RPS modeling efforts and better weigh the potential costs and benefits of RPS policies.

Acknowledgements

The work described in this article was funded by the Office of Electricity Delivery and Energy Reliability (Permitting, Siting and Analysis Division) and the Office of Energy Efficiency and Renewable Energy (Wind & Hydropower Technologies Program) of the U.S. Department of Energy

under Contract No. DE-AC02-05CH11231. We appreciate the funding and continued support of our U.S. Department of Energy colleagues, especially Larry Mansueti, Steve Lindenberg, and Alejandro Moreno.

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